

Rapid Vehicle Sound Quality Benchmarking and Evaluation Using The NVH Vehicle Simulator and SoNoScout Binaural Recording and Analysis System



Situation: Vehicle Sound Quality Evaluation and Target Setting

- Need to evaluate several vehicles for benchmark study with respect to sound quality
 - Full vehicle sound quality
 - Component- or attribute-specific sound quality benchmark from full vehicle level
 - Identify key sound quality features



- Vehicles only available for short time – 1 day or less
- Several people need to evaluate the vehicle
- Typically this means only subjective evaluations are possible, no data recording or analysis

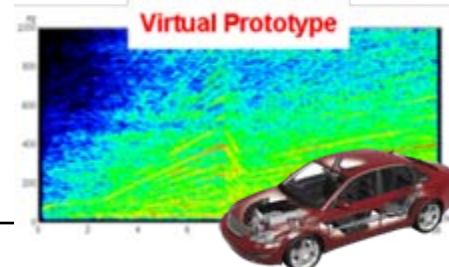
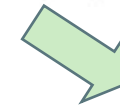
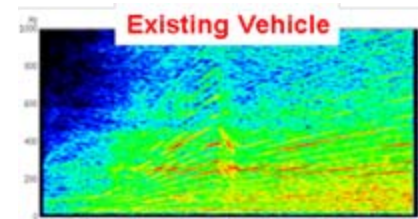
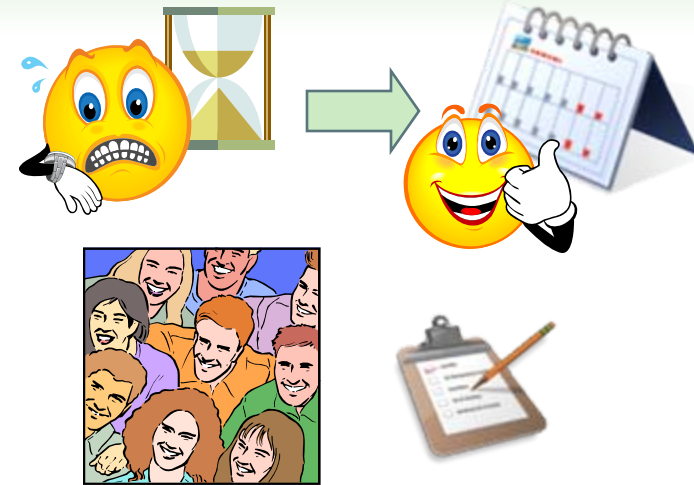
Traditional Approach

- Subjective evaluation of vehicles on test track or road
- For vehicles that are only available for a few hours, no recording/analysis possible – no time for instrumentation (especially tachometers)
- Limited number of people can evaluate vehicles in short amount of time
- **Current cars only**
 - » No Targets
 - » No New Designs
- **Result:**
 - Subjective evaluation only for existing cars with short vehicle availability
 - No record of actual sound levels of sound character of vehicles
 - No record of how people drove during the evaluation
 - Longer periods required for actual testing and analysis




Ideal Situation

- Benchmark vehicles available whenever needed
- Test track available whenever required, without worry of weather problems
- Unlimited number of subjective evaluations
 - All results of subjective evaluations logged and analyzed
- Compare vehicle truly back-to-back, switch instantly between vehicles
- Measure and analyze the interior sound data to identify differences and similarities between vehicles and identify desirable characteristics
- Develop target levels for interior sounds and evaluate these when driving a vehicle, and compare target sound to benchmark vehicles (i.e. drive and experience virtual vehicles – vehicle which do not exist yet)



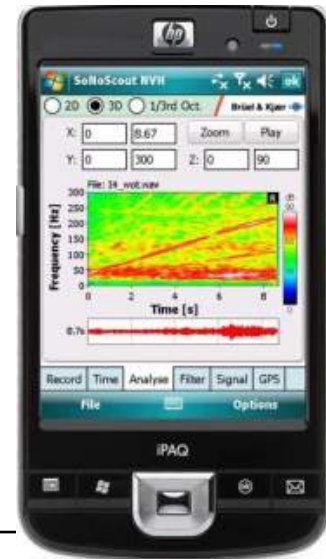
Rapid Sound Quality Benchmarking Approach



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1. Record vehicle sound
 2. Transfer data to virtual vehicle driving simulator
 3. Drive vehicles, evaluate, analyze, manipulated sound

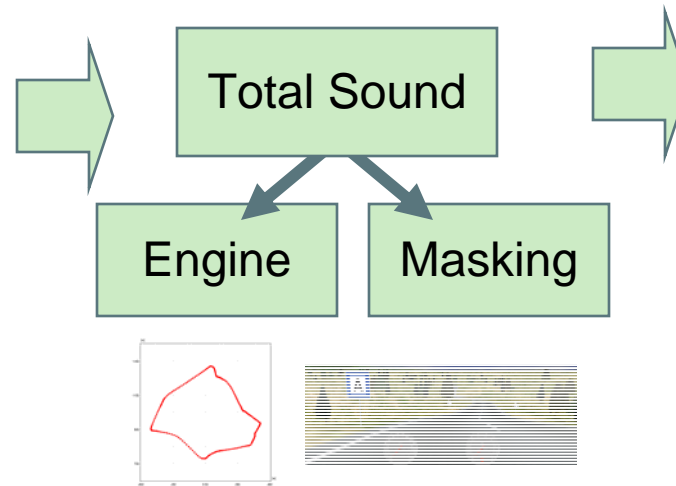
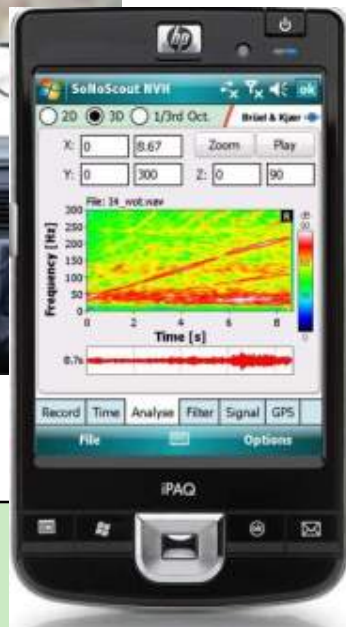
1. Recording Vehicles with SoNoScout

- SoNoScout Binaural Measurement and Analysis system
 - No tachometers required
 - Engine speed calculated from sound measured at driver's ear
 - Vehicle speed calculated from GPS
 - Sounds can be evaluated and replayed on the spot
 - » Time display
 - » FFT 2D/3D displays
 - » Filtering (High Pass, Low Pass, Notch, Order)
- Recording
 - Several conditions recorded to cover operating range of vehicle
 - Recordings can be completed in 15 minutes (same time as required for subjective evaluation by 1 assessor)



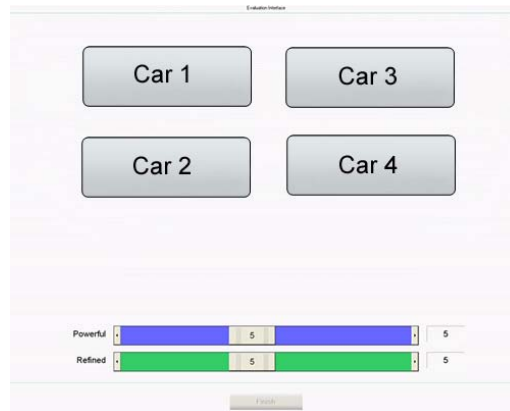
2. Transferring Recordings to NVH Vehicle Simulator

- Recordings are easily processed and transferred to the NVH Vehicle Simulator
 - Sound files are decomposed into their components parts (engine orders and masking)
 - Vehicle performance data calculated from engine and vehicle speed
- Vehicles are prepared for driving in the NVH Vehicle Simulator



3. Driving Vehicles in the NVH Simulator

- Once vehicles loaded into the simulator, they are available to drive in the virtual world
 - Driver-in-the-loop sound simulation – Drive the car just like real car – accelerator pedal, brake, gear shift, steering, etc. with contextual cues (visuals, traffic, sounds)
- Vehicles can be driven and evaluated at any time by any number of people (expert or non-expert)
- Vehicles can be driven back-to-back, instantly switching from one to another



Collecting Driver Subjective Impressions

- Full suite of tools to collect driver evaluations and analyze these results
 - 5 separate methods of evaluation included in the software



- You can also record and analyze how people drive along with their opinions about the sound

Evaluating Subjective Results

- Analysis tools built into NVH Simulator for processing subjective responses

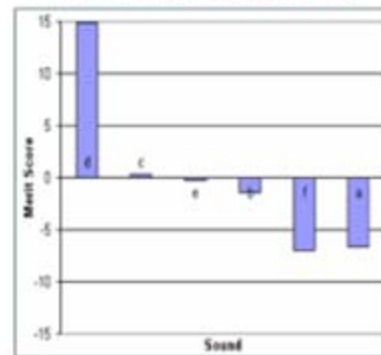
Individual Juror Results

	Car A	Car B	Car C	Car D
Car A		-1	1	-1
Car B	1		1	1
Car C	-1	-1		-1
Car D	1	-1	1	

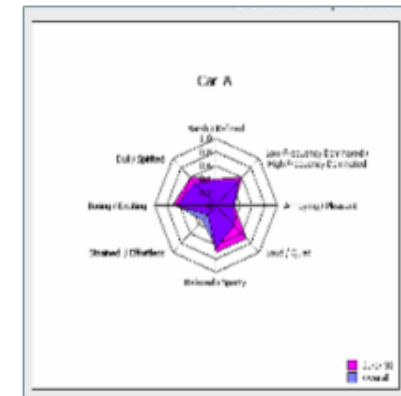
Adjusted Probabilities

	Car A	Car B	Car C	Car D
Car A		0.05	0.25	0.75
Car B	0.95		0.95	0.75
Car C	0.75	0.05		0.25
Car D	0.25	0.25	0.75	

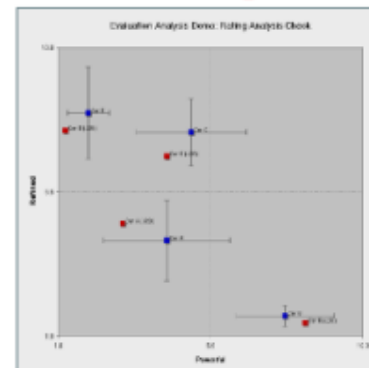
Paired Comparison



Semantic

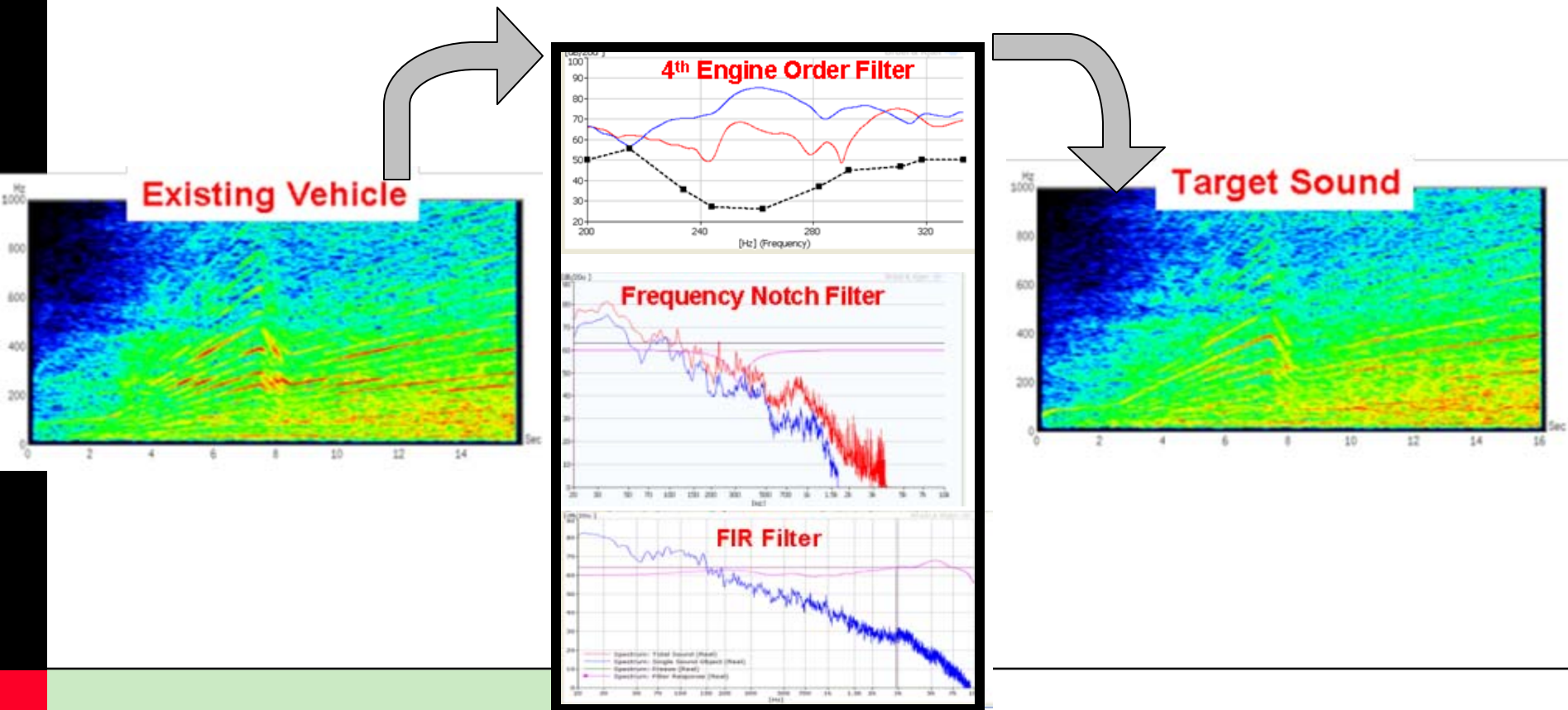


Rating



Modification of Sounds

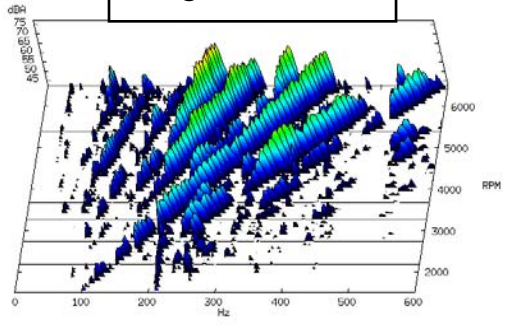
- Something you cannot do in a real car – modify sounds in real-time
- Develop target sounds for your vehicle
- Initiate virtual prototyping



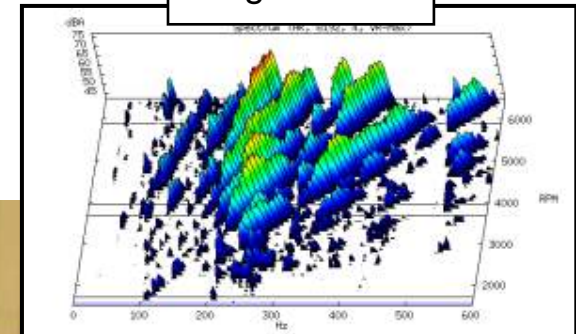
Evaluate Modified Sounds / Targets

- Existing Vehicle, Benchmark vehicle, Target Sound and Virtual Prototype driven in the NVH Driving Simulator
 - Effortlessly communicate vehicle NVH information to those who need to know and make decisions

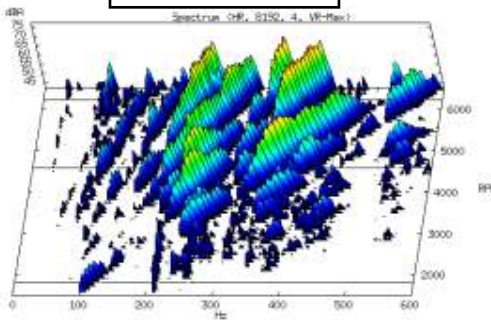
Original Sound



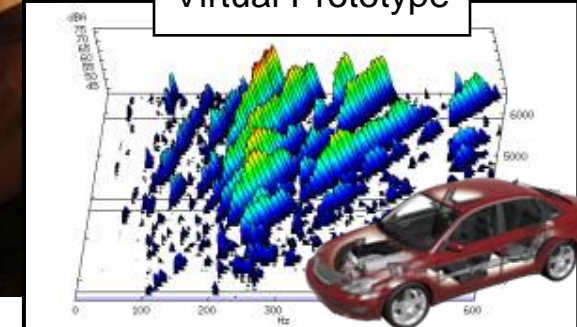
Target Sound



Benchmark



Virtual Prototype



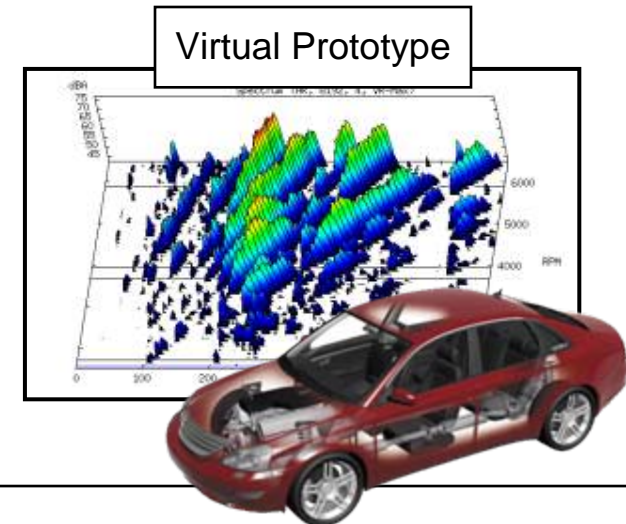
Summary Rapid Sound Quality Benchmarking Approach



1. Record vehicle sound
 - Total time required from start of measurement to driving cars in the simulator – less than 1 day for 4 vehicles.
 - Actual in-vehicle measurements require ~15 minutes per vehicle
 - No need for tachometers on engine or wheel
2. Transfer data to virtual vehicle driving simulator
3. Drive, evaluate, analyze, manipulated sound
 - Real-time, driver-in-the-loop NVH driving simulator
 - Vehicle driven just like real car – accelerator pedal, gear shift, steering
 - Realistic context – Visual display
 - Capture driver preference
 - Modify sounds for target setting and evaluation

Summary

- Multiple vehicles can be recorded, analyzed and driven in the NVH simulator in a single day
 - Measure sound of vehicles rapidly without cumbersome instrumentation using the SoNoScout Binaural Measurement and Analysis System
 - Rapidly transfer these sounds to the NVH Vehicle Simulator
 - Drive the vehicles back-to-back in the virtual environment
 - » No restriction on how many people can drive the vehicles
 - » No concerns of vehicle availability, test track availability, weather, etc.
- Collect driver feedback in the software and analyze driver preference
- Develop targets - Manipulate and modify vehicle sounds, drive the virtual prototype



Contact Information



To learn more about the SoNoScout Binaural Measurement System and NVH Vehicle Simulator, please visit our website at

www.bksv.com

Or call Brüel & Kjær North America headquarters at 1-800-332-2040

NVH Simulator Application Specialist

David Bogema

Senior Application Engineer
Brüel & Kjær North America Inc.

Phone: (734) 620-8057
dave.bogema@bksv.com